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The Rise and Fall of the UK's Spandrel Panel

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Abstract

Spandrel panels are a common feature of many buildings around the world. Their presence is often cited as a measure to prevent vertical fire spread from storey-to-storey. With a focus on the UK's building regulatory system, this paper charts the introduction of the spandrel panel into local building regulations. It is shown how research activities in the mid twentieth century led to a suggestion that the spandrel panel was not an effective means by which to mitigate storey-to-storey fire spread. Combined with the work of Margaret Law on unprotected areas, this led the UK national building regulations to omit the spandrel panel and, in effect, admit defeat with regard to preventing storey-to-storey fire spread via openings in the external wall. The implications of this for modern UK buildings with phased evacuation or 'stay put' strategies are profound. If storey-to-storey fire spread is to be assumed, how should the fire safety strategy be reformulated to account for this? Or if the prevention of storey-to-storey fire spread is, in fact, an objective – what is the mechanism for doing this in the future?

Key words

spandrel panel; vertical fire spread; regulation

1. Introduction

Vertical fire spread in tall buildings is a common hazard and, as such, the mitigation measures typically fall under the scope of building regulations. There are a range of measures that are employed in order to protect against this hazard. However, it is useful to distinguish between three different vertical fire spread hazards. Vertical fire spread can occur due to (1) the propagation of fire on and within the external envelope of a building; (2) the spread of fire between floors due to heat transfer from the external plume; and (3) fire spread due to failure of internal compartmentation. For large fires, there is often some interaction between these modes of spread.

Fire propagation on and within the external envelope of the building has become the subject of much attention due to major fires around the world such as Latrobe Terrace [1], the Address Hotel [2] and, most tragically, the Grenfell Tower fire in 2017 [3]. In this context, much of the focus has been placed on the materials from which the external envelope of the building is constructed. Mitigation methods for this hazard focus on the control of combustible materials; and/or the testing of cladding systems using large scale tests defined in national building regulations (e.g. BS 8414 [4], NFPA 285 [5], and AS 5113 [6] – see Boström et al. [7] for a more comprehensive list). Therefore, the heat flux from the external plume is relevant to mitigating this hazard only in-so-far-as it relates to the boundary conditions imposed on a cladding system.

The spread of fire between floors due to heat from the external plume has attracted less attention in recent years but is, nevertheless, something that has, in modern time, been periodically considered and regulated. The combustible contents of an upper storey have the potential to be ignited due to direct flame impingement by the plume and/or due to radiative heat transfer from the plume either through open (or broken windows) or through unbroken glazing. Methods for mitigation of this hazard typically fall into one or more the following categories.

1. Extended floor slabs. Extended floor slabs are sometimes used to create a stand-off distance between the hot plume and the combustible contents of an upper floor.
2. Spandrel panels. Spandrel panels are sometimes used to ensure that there is a minimum vertical height between openings in a building.
3. Automatic suppression. Sprinklers are frequently cited as a means to mitigate against this hazard. It should be noted that this approach is based on reducing the likelihood of the hazard eventuating – rather than mitigating its consequences.

Examples of these fire protection measures in current prescriptive guidance include NFPA 5000 [8] and Australia's NCC BCA [9] (measures in various other jurisdictions are summarised by White [10]). NFPA 5000 (37.1.4.2) recommends that if a spandrel panel is to be used, then this should provide a minimum separation of 3 feet (or 915 mm) between openings and should be rated to a 1 hour fire resistance standard. Similarly, NCC BCA (C2.6) states that any spandrel should be not less than 900 mm in height, and should be rated to a 1 hour fire resistance standard. Guidance in the United Kingdom (for example England's Approved Document [11], Scotland's Technical Handbook [12], and Northern Ireland's Technical Booklet E [13]) is silent on this topic.

Figure 1 shows a conceptual illustration of the assumed effect of a spandrel panel when compared to a building without a spandrel panel.

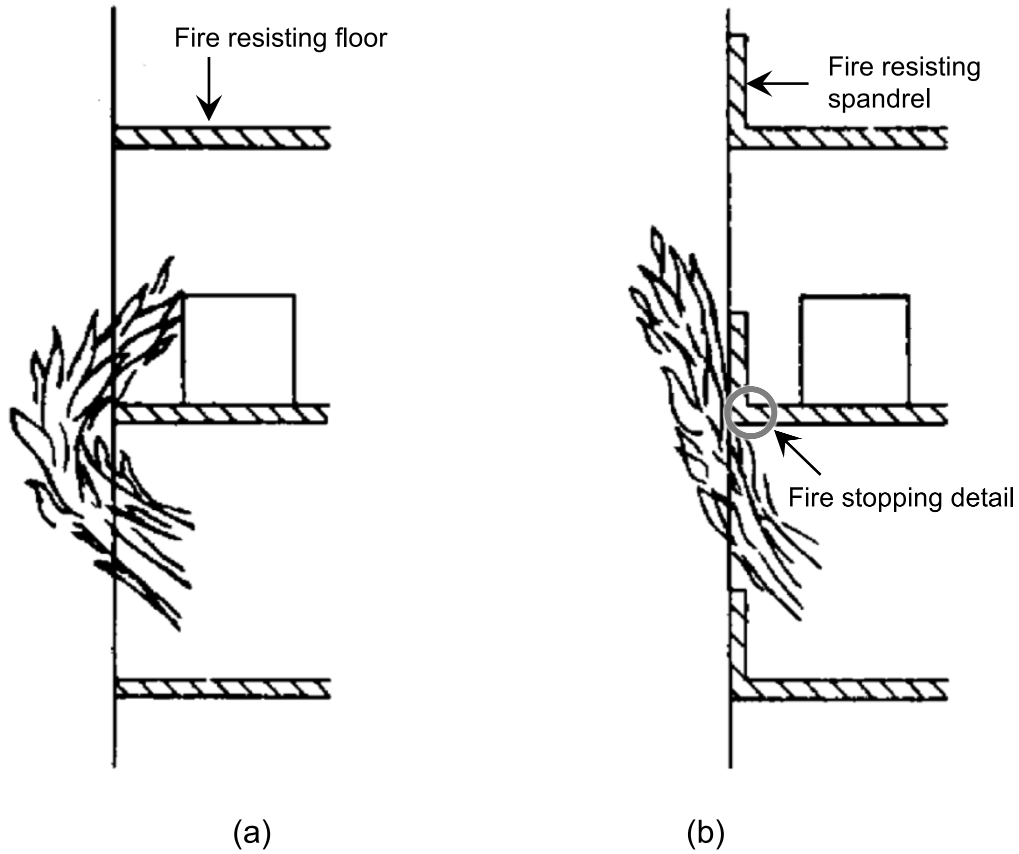

Figure 1 Illustration of the concept of the assumed behaviour flames a) without, and b) with a spandrel panel. Annotated extract from Ashton and Malhotra [14].

Focusing on Scotland, England and London, this paper charts the rise of the spandrel panel from empirical beginnings, to becoming an omnipresent feature of many codes. It is shown how the spandrel panel fell victim to the drive for new and innovative forms of construction, but that the presence of local building acts and by-laws meant that, in reality, the spandrel panel staggered on until the late 20th century. Finally, the implications of this demise are considered in the context of recent fires, the true intent of the UK's building regulations guidance, and the implications for new forms of construction.

2. The Rise

In the late 19th century, building regulations (if present) were an inconsistent patchwork of local bylaws. Each jurisdiction had its own approach to mitigating fire risk. This was cited as the reason for the establishment of NFPA in 1896 [15]. Sprinkler manufacturers recognised that lack of standardisation was a barrier to reliability as different pipe diameters were used in different parts of the same state. Similarly, in the UK, local bylaws controlled the standards of construction, and these varied between different cities, and different boroughs in the same city.

The hazards associated with fire have long been recognised as a shared problem [16] – and therefore one which cannot be left to individuals to mitigate. As a consequence, many fire safety measures feature strongly in local bylaws. Controls on construction materials are frequently cited as originating with great urban conflagrations such as Rome, London and Chicago.

The spandrel panel as a means to mitigate storey-to-storey fire spread first emerged from the North America where, for example, the NFPA Report of the Committee on Building Construction stated that ‘all openings shall have solid wall separation between the bottom of lintels and sills of openings next above of not less than 3 feet [914 mm] and shall have not less than 1 foot [305 mm] of spandrel between the lintel and ceiling’ [17]. Since 1928, the requirement stated in NFPA has not fundamentally changed, sprinklers and slab projections have also been proposed as alternative mitigations. The origins can, no doubt, be traced to earlier guidance and documents – but the focus of this paper is on the UK use of such an empirical approach.

The exact mechanism by which the spandrel panel was intended to prevent fire spread is not entirely clear. However, the presence of a fire resisting element of construction at the spandrel location clearly has several means by which it *could* mitigate storey-to-storey fire spread. A spandrel would provide a thermal barrier to reduce heat transfer to flammable material on upper storeys; it would provide imperforate construction to reduce the potential for direct flame impingement; it would provide some stability to the window frame; and finally, its structural stability would mean that it remained mechanically stable during a fire.

Conventional brick and stone construction naturally introduced a spandrel panel that had some inherently fire resisting properties. Thus, even where a spandrel panel was not required by local bylaws, a fire resisting external wall would frequently have been present simply due to the form of construction. However, the advent of new construction technologies removed the natural tendency to provide a spandrel panel, and in many cases removed the inherent fire resisting properties of the construction used in the external wall. Other authors [18] have charted the emergence of the curtain wall, and have designated a distinction between the technologies of the ‘glass wall’, and the ‘panel wall’. Both technologies rely on lightweight materials (e.g. aluminium), and the careful framing of glazing. A common feature of these technologies is (and was) the use of fixing rails and connection details to the underlying structural system – from which the elements of the curtain wall could be suspended or affixed.

As these technologies emerged (during the interwar period), the forms of constructions that were possible with curtain walling systems therefore became closely linked to specific clauses within local bylaws. This led to very different curtain walling solutions depending on geographic location. An example cited by Yeomans [19] is the difference between Edinburgh, and Hendon (London). In 1937, TP Marwick and Son’s built glass curtain wall in Edinburgh without any fire stopping or spandrels. Conversely, the Daily Express Building on London’s Fleet Street in 1933 had originally been planned to have full height transparent glazing on the external wall – but in the final design, pumice concrete was added to introduce a fire resisting spandrel panel.

In London, the presence of the London Building Act attempted to bring some uniformity to the regulatory approach. Section 20 [20] specified various fire safety measures, however, the act also gave District Surveyors the power to supersede these with additional fire safety measures.

During, and post war, the hazard of fire spread was brought sharply into focus by incendiary bombing, and resulting urban conflagration. In 1946, the Post War Building Studies articulated the hazard of storey-to-storey fire spread as follows: ‘If the storeys of a building are separated at all points from one another by fire resisting construction of a sufficient grade to resist a complete burn-out, there still remains risk of spread of fire between storeys via windows’ [21]. The authors go on to state that ‘A large proportion of window openings markedly accentuates the risk and adds to difficulties of fire-fighting. With average amounts of window openings we felt that it would be onerous to demand [protected windows] in all cases.’ They thus concluded that ‘a reasonable degree of protection could be obtained by providing at least 3 ft. of construction (of which at least 2 ft. should be above floor level) of the same grade of fire resistance as the walls, between the lintel of the lower window and sill of the one above’ [21].

Following the WWII, there was an attempt by the London and Scottish governments to distil the knowledge contained within the Post War Building Studies, and capture this in regulations. The ‘Bylaws’ were a response to this. They were published in England by the Ministry of Communities and Local Government [22] and in Scotland by the Department of Health [23]. Similar legislation was also enacted by London County Council as the London Building (Constructional) By-Laws [24].

Each of these bylaws identified the presence of a spandrel panel as a possible mitigation method for storey-to-storey fire spread. The English ‘model’ bylaws recommended that the spandrel should be a minimum of 3 ft (914 mm) high; the Scottish bylaws required that the spandrel should be a minimum of 3 ft high; and the London bylaws required that the spandrel should be a minimum of 2 ft 6 in (762 mm) height. Legislation made a clear distinction between external ‘walls’ which were intended to confine fire within the building until it burnt itself out, and limiting ‘openings’ in order to prevent spread of the fire [25].

However, the 1950s was a time of change in the construction industry. The curtain wall was a technology whose time had come, and systems that had been pioneered in the early 20th century were becoming increasingly favoured as a form of construction [18]. It was noted that legislation based on the idea of solid external ‘walls’, with window ‘openings’ had been rendered obsolete by these new cladding technologies [25]. However, in the late 1950s, the by-laws placed a significant constraint on such systems – that is, the requirement for a fire resisting spandrel panel.

3. Turning Point

In the late 1950, the UK government’s Joint Fire Research Organization began a research project into the use of spandrel panels [14]. The motivation for the research was very clear, it was intended to determine whether ‘relaxations could be justified’ from spandrel panel requirements in the bylaws [14]. It was acknowledged that the present requirements were ‘restrictive in the use of some forms of construction which were desirable for other reasons’ [14]. The researchers (Ashton and Malhotra), highlight that there were differences in the view on the magnitude of the hazard presented by window-to-window fire spread; they therefore undertook a large-scale experimental study to investigate the effectiveness of the spandrel panel.

Ashton and Malhotra undertook a series of eleven tests on a four-storey building. They created several different arrangements, and for the curtain walling system the intent was that the system was ‘representative of current practice in all details’ [26]. Spandrels were constructed from material such as plasterboard and asbestos cement sheet. During some of the experiments full height glazing was used. Unlike a ‘glass wall’ type cladding system, typical of a curtain wall, this appears to have been constructed from windows fitted in the opening between the floor and the soffit.

Most of the tests had a fuel load of 10 lb/ft^2 (approximately 850 MJ/m^2). An unknown number of thermocouples were placed in the compartment of origin with additional thermocouples placed at the upper storeys. There appears to have been some variation between the tests in terms of the arrangement of flammable materials at the upper storeys; some test had furniture, while curtains were added in the later tests. In addition to the thermocouples measurements, visual observations were made. In each case, a fire was ignited on the ground floor, and the resulting behaviour of the various cladding systems was noted.

The conclusions from this work were profound both at the time, and when viewed from the prism of recent events. Ashton and Malhotra found that the severity of the fire attack from the external flames was less than the severity within the compartment; but that even *with* a spandrel panel, the glazing on the floor above a fire could break and that this could result in fire spread to the upper storey. Based on these observations, they concluded that a 3 ft [914 mm] spandrel panel was an ‘inadequate’ measure to prevent the spread of fire from storey-to-storey [14]. They suggested therefore that the fire resistance requirement for a spandrel panel could be reduced ‘even below a half hour without any significant reduction in fire safety to a building or its occupants’ [14].

Ashton and Malhotra’s approach was a pragmatic one. They reasoned that if the current mitigations for storey-to-storey fire spread were not effective, then they might as well be omitted from the regulatory requirements. They did not appear to consider, however, whether an alternative mitigation approach should be enacted. Ashton and Malhotra also did not appear to consider whether the spandrel may have offered some benefit (or benefit in some cases), even if that benefit was not universal or absolute. Writing in the architect’s journal in 1964 Ashton and Malhotra again presented their research [26]. They concluded that the results showed that ‘a light alloy could be designed to achieve in its own right the standard of fire protection specified in local authority bylaws’. They also recognised that detailing of the curtain walling system was important – they identified essential features as being ‘separate anchoring of the cladding panels to the building and sealing of gaps between the edge of the floor slab and the cladding panels by a method capable of surviving exposure to fire’.

4. The Long Fall

At the same time that Ashton and Malhotra were researching storey-to-storey fire spread, Margaret Law (also at the Joint Fire Research Organisation) was investigating the measures necessary to prevent building-to-building fire spread [27]. This work allowed Law to establish a relationship between the maximum allowable area of unprotected openings on the external wall of a building, and the distance to a neighbouring building (or site boundary). She suggested that if the external wall was sufficiently far from neighbouring buildings, then the external wall did not require fire resistance.

In 1963, Scotland implemented national building regulations [28]; and in 1965, England followed [29]. The new national building regulations drew heavily on the recent research. Together the work of Margaret Law and the work of Ashton and Malhotra enabled the removal of the requirement to provide a fire resisting spandrel panel. The new regulations included the tables developed by Law to calculate permissible separation distances between buildings. In the new national regulations, the fire resistance requirements for external walls were therefore tied only to the maximum permissible areas that Law had previously described.

To provide context for the new building regulations, the then Director of the Fire Research Station (G. J. Langdon-Thomas) wrote 'Fire Note 8' with Margaret Law [23]. This note followed the same logic as Ashton and Malhotra. They wrote that 'to provide adequate protection it would be necessary virtually to omit all windows from the storey immediately above the one with openings in it'. In relation to the use of a protruding slab, they also noted that 'in order to be effective a much greater distance of projection than 2 ft from the face of the wall would be needed'. They noted that where no fire resistant panel was present, ignition of furniture in the room above the fire compartment would not occur 'for as long as 15 minutes'. They concluded that 'the enclosure of a building has little to contribute to the reduction of fire spread within a building and that a substantial relaxation could be made in the structural design requirements for external walls'.

However, although the spandrel panel was absent from the national regulations, this fire safety measure was preserved in some jurisdictions by the presence of many Local Acts and associated bylaws. Taking London as a case study, section 6.08(2)a of the London Building (Constructional) Amending By-laws 1964 required that a 3 ft spandrel panel be provided between windows on the external wall [30]. Similarly, the 1972 version of the London Bylaws required that a 900 mm spandrel panel should be provided.

Between 1965, and 1983, there were multiple updates to the English building regulations. Each of these updates retained the Law method for calculating building-to-building separation, and omitted any requirement for a spandrel panel. However, the local acts (and their bylaws) continued to ensure that a spandrel panel was present in some jurisdictions. In 1985, England adopted the functional requirements approach to fire safety regulation [31]. As a consequence, specific fire safety measures were dropped from the building regulations. Instead, they were captured in the Approved Documents and their supporting documentation. In 1985, the scope of the London Building Act was also restricted [32] in order to 'harmonize' [32] the fire safety measures in section 20 with those described in the new Approved Document [33]. The scope of section 20 was therefore reduced such that a District Surveyor could no longer require spandrel panels.

Law's enclosing rectangles method was reprinted in the appendix of the first Approved Document (ADB) – and in later editions was relegated to a separate supporting document (BR 187 [34]). The requirement for spandrel panels never returned. In relation to the junction of the compartment floor and the external wall, ADB [33] notes that 'where a compartment… floor meets… an external wall… they should be bonded together or fire-stopped'. Reflecting on this in 1986, Malhotra noted that his work in the 1950s had been 'used as a basis for the relaxation of obligatory window separation' [35]

Similarly, in Scotland, the national building regulations were updated regularly until 1990, at which time the first of (what became) the Technical Handbooks was published [36]. The first of these documents also reprinted Law's enclosing rectangles method, and omitted the spandrel panel. In the same manner as ADB, it was noted that where a 'compartment floor meets and external wall… the junction must be fire stopped.'

The new guidance to the building regulations were the end of the spandrel panel in the UK. The final repeal of much of the local Acts took place in 2012 on the basis that 'local Acts have no statistically significant impact as far as life safety aspects are concerned' and that 'for tall buildings, there was little benefit, as the inherent degree of compartmentation is sufficient to prevent most fires getting "big"' [36]. By this time, of course, the spandrel had been absent from legislation enabled by the London Building Act for nearly 30 years.

5. Implications

The story of the rise and fall of the spandrel panel raises some technical and regulatory questions. The first is whether or not Ashton, Malhotra, Langdon-Thomas and Law were correct that the spandrel panel offered no meaningful benefit. Reviews by other authors have pointed to similar conclusions [37–39]. Nevertheless, spandrel panels continue to be used in other jurisdictions. The authors do not propose to attempt to answer this question herein, as presumably the answer is 'it depends'.

However, if we accept the conclusions of Fire Note 8, this leads to a further (more disturbing) question. Langdon-Thomas and Law stated that 'to provide adequate protection it would be necessary virtually to omit all windows from the storey immediately above the one with openings in it'. They therefore opted simply to not protect against this hazard. In effect, by making this decision they decided that *inadequate* protection against vertical fire spread, was an acceptable standard of performance.

This leads to the suggestion that, unless the fire could be suppressed by another means (e.g. sprinklers or fire service intervention), there was a degree of inevitability about the potential for fire spread. The implications on egress of this inevitable fire spread were clear. For example, in 1960 it had been noted in the Architect's Journal that the reason why the Ministry of Education had a 'liberal attitude' to the provision of spandrels in light cladding systems was because they had 'stringent and definite requirements for means of escape' [25]. At the time, there was a hope that future legislation would reduce the requirements for the fire resistance in external walls, 'provided that adequate and effective means of escape' were used [25]. However, there was no rethink of means of escape. As noted by Todd [40] with reference to blocks of flats, updated egress guidance in 1971 [40] was based on the assumption that the effective compartmentation demanded by the building regulations was sufficient that it should no longer be 'assumed that entire storeys, or even adjoining flats, need be evacuated if a fire occurred in a flat'. Todd notes that this evacuation 'principle became known as "stay put"'.

Similarly, the mitigation frequency cited in the USA or Australia (sprinklers) were not recommended as mandatory in many buildings until 1992, in England [41]. It therefore appears that there were no specific fire safety measures enacted to compensate for hazard of storey-to-storey fire spread. Langdon-Thomas and Law had determined that it was not reasonable to prevent (or attempt to mitigate) storey-to-storey fire spread – and this decision became enacted within national regulations.

5.1. Intent of the Code

One of the most critical aspects in implementing any fire safety design code is to ensure that the intent of the code has been met. In the context of a system of functional requirements (as in the UK) this is a necessary part of the due diligence that any designer must undertake when applying guidance documents. In England, the Building Regulations 1965 substantially changed the intent of the code. Previously, it had been the intent of many bylaws to mitigate (or prevent) storey-to-storey fire spread. After this date, it appears that (enabled by Langdon-Thomas and Law) the national regulations no longer intended to mitigate storey-to-storey spread via the outside of the building. However, where the spandrel panel was still enforced by local acts (e.g. in London) the intent of these codes remained to mitigate or prevent storey-to-storey fire spread.

For around two decades in the UK, there were therefore two opposing regulatory intents operating simultaneously. One approach accepted vertical fire spread as inevitable; the other attempted to mitigate this hazard by the use of the fire resistant spandrel. Whether the spandrel panel could mitigate storey-to-storey fire spread, seemed to be a matter of faith on the part of the authority having jurisdiction.

However, these two different approaches to storey-to-storey fire spread suggest very different fire safety strategies. If it is to be assumed that storey-to-storey fire spread is inevitable, then one might expect the fire safety strategy of a building to be devised around the assumption that, at some point, it might be necessary to make an evacuation. Conversely, if it is assumed that storey-to-storey fire spread is prevented by the spandrel then a ‘stay put’ strategy (or some other long duration phased evacuation) could be assumed as being effective.

Within the UK, the ‘stay put’ strategy is supposed to allow occupants to escape should they wish. However, historically, there has been no means to initiate a building-wide or storey-by-storey evacuation other than by fire service personnel knocking on doors. This approach appears to be consistent with the assumption that fire will be contained within the flat of origin (i.e. the spandrel panel approach). Conversely, if there is no attempt to mitigate storey-to-storey fire spread or apply regulatory control to this hazard, then it cannot be assumed that that containment of the fire to the storey of origin will be an inevitable outcome. In such cases it is incongruous to assume that a wider building evacuation will not be necessary.

The inconsistency of this approach was identified during revisions to the Approved Documents that took place in the early 1990s. Davis noted that ‘it does not seem logical to require a high standard of fire separation in walls and floors yet, once outside the building, fire can traverse the external wall and bypass the internal separation’ [42]. Addressing this issue as part of a review of fire spread via windows in 2002, Crook [38] echoed the approach of Langdon-Thomas and Law some 40 years earlier – noting that research had ‘shown that spandrel walls need to be of impractical height to be effective for controlling vertical fire spread’ and concluded that storey-to-storey fire spread was ‘not a significant threat to life compared with the other risks from fire in tall buildings’ [38]. Crook thus concluded that ‘measures currently called upon through Approved Document B are still commensurate with the risk’ [38] and that no specific controls or mitigations need be applied to this hazard.

5.2. Fire Stopping and New Forms of Construction

While there may have been acceptance of storey-to-storey fire spread via the openings in an external wall, the removal of regulatory controls from the spandrel also has implications for internal fire spread.

In the case of Ashton and Malhotra, the forms of construction used in their experiments could be (and were) readily fire stopped. They recognised the effectiveness of this fire stopping and this led to their emphasis that an essential fire safety feature should be the 'sealing of gaps between the edge of the floor slab and cladding panels by a method capable of surviving exposure to fire' [26]. Without an effective seal there is the potential for fire to spread internally within the building through gaps between the external wall in the compartment floor – a point also noted by Crook in 2002 [38].

However, Malhotra and Ashton's 'fully glazed' wall was also very different from a modern glazed curtain walling. The decision of Langdon-Thomas and Law to no longer regulate the spandrel panel immediately changed the cladding assemblies that could be used on external wall construction. For some modern cladding systems, it may appear impossible to provide meaningful fire stopping between the external wall and the floor slab. In the absence of regulatory control for the spandrel, the need for fire stopping may therefore appear surprising; attempts to provide such fire stopping may appear absurd.

When viewed in the context of Ashton and Malhotra's experiments, the need for fire stopping emerges. Whether or not a form of construction can be effectively fire stopped in order to achieve the performance desired by Ashton and Malhotra is something that the designer would need to evaluate on a case-by-case basis. It is perhaps possible that some new forms of construction may not permit fire stopping (or mitigate internal fire spread) in the way that Ashton and Malhotra had intended.

While some new forms of construction may introduce vulnerability, it is possible that other aspects of modern construction may provide better performance. For example, the experiments conducted by Malhotra and Ashton were performed late 1950s and the glazing that they found to be so vulnerable to cracking would only have had a single pane of glass. It is reasonable, therefore, to ask whether their conclusions would be the same if they undertook the same experiments today. Would today's triple pane toughed glazing be as vulnerable to fire as the glazing of the 1950s? Would a spandrel panel combined with modern glazing prevent storey-to-storey fire spread? Would modern glazing prevent storey-to-storey fire spread without any additional measures? Scoping research by Holland touched upon some of these issues [43].

There is also the question of the fire. Is the thermal attack of a modern fire equivalent to the fires that Ashton and Malhotra set in the late 1950s? Recent evidence from large scale compartment experiments on mass timber-lined compartments suggest that the heat fluxes on the cladding (or opening) above the compartment can be two times greater than for a conventional compartment fire [44].

These questions are of paramount importance as the UK's governments consider their response to the Grenfell Tower fire. If the prevention of storey-to-storey fire spread is an objective, what is the mechanism for doing this? If storey-to-storey fire spread is to be assumed, how should the fire safety strategy be reformulated to account for this? Is regulatory control of the spandrel needed in order to assure adequate performance of fire stopping?

6. Conclusion

The spandrel panel is an established means to mitigate the hazard of storey-to-storey fire spread in many jurisdictions. However, it is also a mitigation whose effectiveness has been periodically questioned. The most influential challenge to the spandrel panel was made by Ashton and Malhotra – who concluded that the spandrel did not provide adequate protection against storey-to-storey fire spread. Combined with the work of Margaret Law on unprotected areas, this led the UK national building regulations to omit the spandrel panel and, in effect, admit defeat with regard to preventing storey-to-storey fire spread via openings in the external wall.

This defeatist attitude has profound implications for the fire safety strategy in tall buildings in the UK. It suggests that storey-to-storey fire spread must always be assumed for such buildings. As such, while 'stay put' strategies are, perhaps, preferable for a host of different reasons – this logic suggests that the need for a wider building evacuation should be an inherent component of UK national guidance documents.

The demise of the spandrel panel in the UK also raises the question of whether Ashton and Malhotra were right to conclude that the spandrel panel was ineffective? Subsequent authors have shown that heat fluxes high enough to promote fire spread may be expected far above the top of a 900 mm spandrel, but given the changes in window technology in the last 60 years, would Ashton and Malhotra have reached the same conclusion if they were working with contemporary building products?

Similarly, by removing regulatory controls from this hazard, Langdon-Thomas and Law enabled a proliferation of new cladding systems that did not necessarily have any fire resisting qualities. These changes have the potential to undermine the performance of fire stopping between the external wall and the compartment floor.

As governments around the world consider their regulatory approach to mitigating vertical fire spread, this is an opportune moment to take stock of previous work, evaluate assumptions embedded within guidance, and ensure that future buildings are created with a coherent set of design assumptions.

7. Acknowledgements

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8. References

[1] Post Incident Analysis Report; Lacrosse Docklands; 673-685 La Trobe Street, Docklands, Melbourne Fire Brigade, Richmond, 2014.

[2] L. Hampele, Dubai hotel fire: The Address Downtown hotel engulfed in flames, BBC News Website. (2016). https://www.bbc.co.uk/news/video_and_audio/headlines/35208484/dubai-hotel-fire-the-address-downtown-hotel-engulfed-in-flames (accessed February 20, 2020).

[3] M. Moore-Bick, Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017. Volume 1, London, 2019. https://www.grenfelltowerinquiry.org.uk/phase-1-report (accessed April 19, 2020)

[4] BS 8414-1:2015, Fire performance of external cladding systems. Test methods for non-loadbearing external cladding systems applied to the face of a building, BSI, 2015.

[5] NFPA 285 Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components, Qunicy, 2019.

[6] AS 5113:2016 Fire propagation testing and classification of external walls of buildings, Standards Australia, 2016.

[7] L. Boström, A. Hofmann-Böllinghaus, S. Colwell, R. Chiva, P. Tóth, I. Moder, J. Sjöström, J. Anderson, D. Lange, Development of a European approach to assess the fire performance of facades, Brussels, 2018. https://op.europa.eu/en/publication-detail/-/publication/81b91f55-af69-11e8-99ee-01aa75ed71a1/language-en/format-PDF (accessed 19 April 2020).

[8] NFPA 5000 Building Construction and Safety Code, National Fire Protection Association, Qunicy, 2018.

[9] NCC 2016 Building Code of Australia - Volume 1, The Australian Building Codes Board, Canberra, 2016.

[10] N. White, M. Delichatsios, Fire Hazards of Exterior Wall Assemblies Containing Combustible Components, Springer, New York, 2015. doi: 10.1007/978-1-4939-2898-9.

[11] Approved Document B - Volume 1: Dwellings, HM Government, London 2019. https://www.gov.uk/government/publications/fire-safety-approved-document-b (accessed April 19 2020).

[12] Technical Handbook - Domestic, Scottish Government Local Government and Communities Directorate, 2019. https://www.gov.scot/publications/building-standards-technical-handbook-2019-domestic/ (accessed April 19 2020).

[13] Technical Booklet E - Fire Safety, Department of Finance and Personnel, 2012. https://www.finance-ni.gov.uk/publications/technical-booklet-e (accessed April 19 2020)

[14] L.A. Ashton, H.L. Malhotra, Fire Research Note 436. External Walls of Buildings - Part I. The Protection of Openings against Spread of Fire from Storey to Storey, Fire Research Station, Boreham Wood, 1960. https://www.iafss.org/publications/frn/436/-1/view/frn_436.pdf (accessed April 19 2020).

[15] C.C. Grant, History of NFPA, NFPA Website. (n.d.). https://www.nfpa.org/About-NFPA/NFPA-overview/History-of-NFPA (accessed February 20, 2020).

[16] G. Bankoff, U. Lübken, J. Sand, Flammable Cities Urban Conflagration and the Making of the Modern World, University of Wisconsin Press, Madison, 2012.

[17] Proceedings of Thirty-second annual meeting, in: National Fire Protection Association Proceedings Thirty-Second Annual Meeting, p. 235, Atlantic City, 1928.

[18] D. Yeomans, The Origins of the Modern Curtain Wall, APT Bull. J. Preserv. Technol. 32 (2001) 13–18. doi: 10.2307/1504688.

[19] D. Yeomans, The pre-history of the curtain wall, Constr. Hist. 14 (1998) 59–82.

[20] London Building Acts (1930-1939).

[21] Fire Grading of Buildings, Part I, in: Post-War Build. Stud. No. 20, HMSO, London, 1946.

[22] Modal byelaws; Series IV; Buildings, London, 1952.

[23] G.J. Langdon-Thomas, M. Law, Fire Note 8: Fire and the External Wall, Ministry of Technology and Fire Office's Committee Joint Fire Research Organisation, London, 1966.

[24] London Building (Constructional) By-Laws, 1952.

[25] R.M. Rostron, Construction: General; light cladding, 4 fire resistance, Archit. J. 131 (1960) 437–440.

[26] L.A. Ashton, H.L. Malhotra, Technical study: Curtain Walling and Fire Protection, Archit. J. 140 (1964) 1059–1064.

[27] M. Law, Heat radiation from fires and building separation, Fire Research Technical Paper No. 5. (1963).

[28] Building Standards (Scotland) Regulations 1963.

[29] The Building Regulations 1965.

[30] London Building (Constructional) Amending By-laws (No. 1) 1964.

[31] The Building Regulations 1985.

[32] London District Surveyors Association Fire Safety Guide No 1; Fire Safety in Section 20 Buildings, 1997.

[33] Approved Document B, B2/3/4, London, 1985.

[34] R. Chitty, BR 187 External fire spread: Building separation and boundary distances, IHS BRE Press, Watford, 2014.

[35] H.L. Malhotra, Fire Safety in Buildings, Department of the Environment, Building Research Establishment, Fire Research Station, Borehamwood, 1986.

[36] Technical Standards for Compliance with the Buildings Standards (Scotland) Regulations 1990, Edinburgh, 1990.

[37] D.J. O'Connor, The Building Envelope: Fire Spread, Construction Features and Loss Examples, in: M.J. Hurley (Ed.), SFPE Handb. Fire Prot. Eng., Springer, 2016: pp. 3242–3282.

[38] C. Crook, DTLR Closing Report: External Fire Spread Via Windows, Garston, 2002.

[39] I. Oleszkiewicz, Vertical separation of windows using spandrel walls and horizontal projections, Fire Technol. 27 (1991) 334–340. doi: 10.1007/BF01039884.

[40] C. Todd, Report for The Grenfell Tower Inquiry; Legislation, Guidance, and Enforcing Authorities Relevant to Fire Safety Measures at Grenfell Tower, Farnham, 2018. https://www.grenfelltowerinquiry.org.uk/evidence/colin-todds-expert-report

[41] Approved Document B, 1992.

[42] L. Davis, Fire Regs Consultation B4 External Fire Spread, Archit. J. 191 (1990) 61–63.

[43] Ciara Holland, David Crowder, Martin Shipp, Nathan Cole, External Fire Spread - Part 2 Experimental Research, BRE, 2016

[44] A. Bartlett, A. Law, R.J. McNamee, J. Zehfuss, S. Mohaine, C. Tessier, L. Bisby, Heat fluxes to a Facade Resulting from Compartment Fires with Combustible and Non-Combustible Ceilings, in: Int. Symp. Fire Saf. Facades, 2019.